Flood in the U.S.: Restructuring the Systems for Risk Assessment and Financing

by

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Abstract

Hurricane Florence made landfall near Wrightsville Beach, North Carolina in the morning of September 14th, 2018. The storm hovered over the Carolinas for the next three days, dropping nearly three feet of rain, which caused devastating and deadly flooding in the region. It is estimated that only about 15% of the losses caused by the hurricane in North Carolina will be covered by insurance due to the exclusion of flood damage from most homeowners policies. Florence brought national attention to the underinsurance of flood risk not only in North Carolina, but across the United States. The National Flood Insurance Program (NFIP) has been the primary provider of flood insurance in the United States since its inception in 1968 with upwards of 5 million contracts currently in force. The private market has been continually involved in flood insurance through the administration of NFIP policies but had shown no interest in assuming the underlying flood risk until recent years. With the NFIP up for reauthorization in May 2019 and the desire of private insurers to acquire flood risk, the United States flood insurance market is facing what could be drastic changes. However, the NFIP is not likely to disappear, and there are still numerous challenges private insurers have to overcome in order to gain market share. While the interaction between private and public sectors in the emerging flood market is uncertain, one thing is known for sure: in order for progress to be made, the underlying issue of underinsurance must be addressed which will require the discussion around flood insurance to change.

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1 Hurricane Florence

1.1 The Storm

Hurricane Florence originated from a strong tropical wave off the coast of Africa on August 30th, 2018, and, over the next day, steadily evolved into a tropical depression near Cape Verde. As the storm continued to progress along a west-northwest trajectory, it rose to tropical storm strength on September 1st and continued to fluctuate in strength over the next few days. Florence gained national attention on September 5th, when unexpected intensification culminated in the storm becoming a Category 4 hurricane. The storm's intensity continued to vary over the next few days as it moved towards the Carolina coast. As the threat of a major impact became apparent, the governors of North Carolina, South Carolina, Virginia, Georgia, and Maryland, and the mayor of Washington D.C. declared a state of emergency, and on September 10th and 11th, North Carolina, South Carolina, and Virginia issued mandatory evacuation orders to many coastal communities. Florence made landfall on September 14th just south of Wrightsville Beach, NC as a Category 1 hurricane with sustained winds of 90 miles per hour (National Weather Service, 2018). Florence continued to move west across the Carolinas, before advancing north through Virginia and finally downgrading to a post-tropical cyclone over West Virginia on September 17th and dispersing into another frontal storm two days later.

1.2 The Impact

Although Florence had enough wind speed to uproot trees, cause widespread power outages, and spawn multiple tornados, most of the destruction was a result of the massive amounts of rain the hurricane brought. Florence became the wettest tropical cyclone recorded in North Carolina history with rain in excess of 30 inches recorded in multiple NC towns; post-storm rain totals across the Southeast can be seen in Figure 1 (Armstrong, 2019). Over

2,200 primary and secondary roads in North Carolina were closed due to flooding including large sections of major interstates. The city of Wilmington became completely isolated during the height of the storm as all roads to the city flooded and were deemed impassable. Florence resulted in a total of 53 fatalities across three states: 41 in NC, 10 in SC, and 2 in VA (Paul et al., 2019). In North Carolina alone 5,214 people were rescued from flooding, an estimated 74,563 structures were flooded, and nearly 140,000 citizens registered for disaster assistance (Armstrong, 2019). The United States Geological Survey published that nine different river gauges across North Carolina reported floods exceeding their 1-in-500 year expectations (Armstrong, 2019).

This extreme weather led to economic losses across the region as well. As of September 25th, State Farm, the largest property insurer in both North and South Carolina, had received approximately 2,840 auto claims and approximately 16,800 homeowner claims across the two states (O'Connor, 2018). Hurricane Florence hit NC during harvest time for many of the state's major crops resulting in losses exceeding $1.1 billion from damage to crops and livestock (Karst, 2018). On October 31st, Governor Roy Cooper's office issued a total damage estimate for North Carolina of nearly $17 billion (Insurance Journal 2018). However, losses to insurers were tempered due to the nature of the storm being a rain rather than wind event. Flood damage is an exclusion in most insurance policies, so while total losses in NC soared, estimates from modeling companies AIR Worldwide and Karen Clark & Co. place the insured losses from the storm in the $1.7 to $4.6 billion range (O'Connor, 2018). The damage from just one inch of floodwater in an average home amounts to around $20,000, meaning that flood damage can have major financial implications for uninsured homeowners (Williams, n.d.). Those who suffered losses and lack flood insurance coverage can apply for Federal Emergency Aid, however assistance is not available after every storm and can take months or even years to reach victims and often poorly matches needs (Kousky, Kunreuther, Lingle, & Shabman, 2018).

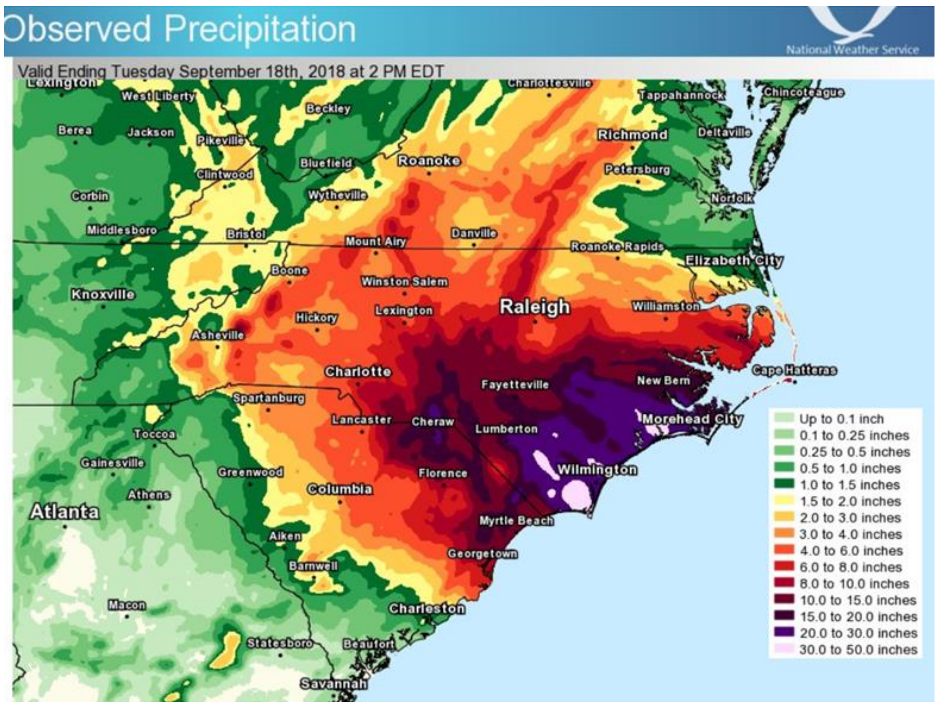

Figure 1 (National Weather Service, 2018)

2 Flood Risk

2.1 Underinsurance of Flood Risk in the United States

The $12 billion plus difference between total and insured losses from Hurricane Florence exposes the extent to which flood risk is underinsured in North Carolina. However, this issue extends across the United States; looking back at the 2017 hurricane season, Harvey, Irma, and Maria had a combined total cost of damage of $217 billion with only $92 billion being covered by insurance realizing a $125 billion insurance gap (Lloyd's, 2019). The underinsurance of flood risk has severe financial implications for individuals as well as communities. Lloyd's city risk index lists flooding as contributing $12.55 billion to the

United States' GDP at risk and $42.91 billion of the global GDP at risk (Lloyd's 2018). Flood insurance provides the necessary financial assistance to cover the cost of repair and rebuilding; the department of Housing and Urban Development found that insured households were 37% more likely to have rebuilt their homes after Hurricanes Katrina and Rita (Kousky et al., 2018). Flood insurance is a necessary product to limit the local and global impact of severe flooding events and to ensure the resilience of impacted communities. Despite the known benefits of insurance, the flood insurance gap continues to persist throughout the United States.

2.2 Brief History of Flood Coverage

The concept of adverse selection is what ultimately led private insurers to withdraw from the flood insurance market. Private insurers offered this coverage from about 1895 to 1927, but only customers in areas prone to flooding were purchasing it (National Resource Council, 2015). Even with effective underwriting, insurers still had to charge an affordable premium which ultimately led to more claims being paid out than premiums brought in. Losses caused by the 1927 Mississippi River Floods as well as additional 1928 losses resulted in insurers terminating their flood coverages and withdrawing from the market (National Resource Council, 2015). Flood risk is not covered by the private insurance market simply because they found it to be an unprofitable product.

3 The National Flood Insurance Program (NFIP)

3.1 History

The National Flood Insurance Program (NFIP) was created in response to the withdrawal of private insurers from the flood insurance market. Without flood insurance to cover a portion of the losses, the federal government was increasingly asked to provide disaster relief after flooding events. It was President Truman who first proposed the request to congress to "establish a national system of flood disaster insurance" in 1951 (National Resource Council, 2015). After a series of severe loss events in the 60s, President Johnson created a task force who wrote a report titled *A Unified National Program for Managing Flood Losses*; this report, along with congressional testimony from the Department of Housing and Urban Development (HUD) was the origin of the original NFIP legislation (National Resource Council, 2015). The National Flood Insurance Act of 1968 created the National Flood Insurance Program to be administered by HUD, and although it has been modified many times, the act is still the legislative foundation of the NFIP. When created, the National Flood Insurance program had two main objectives: to encourage state and local governments to constrict the development of land exposed to flood hazards, and to provide flood insurance through a cooperative cost sharing program between public and private sectors. However, within a decade, the sharing program had been abandoned, and the NFIP took full responsibility of rate setting and risk bearing (National Resource Council, 2015). The 2012 reauthorization of the National Flood insurance program included provisions aimed at encouraging private flood insurance; legislation passed the house in the 114th congress but was not taken up by the Senate before the end of the Congress (Horn & Webel, 2018). Therefore, most flood insurance coverage in the United States is still through the NFIP.

In the past 10 years, there have been various pieces of legislation passed that significantly impact the National Flood Insurance Program. The Biggert-Waters Flood Insurance Reform Act of 2012 was passed to address the fiscal insolvency of the NFIP by funding the national mapping program and allowing certain rate increases to transition the program from subsidized to full actuarial rates reflective of true risk (FEMA, 2018c). In

2014, the Consolidated Appropriations Act prohibited the implementation of certain parts of Biggert-Waters, effectively stopping certain rate increases, while new law was developed to address concerns related to raising rates (FEMA, 2018c). As a result, the Homeowner Flood Insurance Affordability Act of 2014 repealed certain parts of Biggert-Waters, restored grandfathering (allowing low rates remain even if risk is found to be higher), put limits on rate increases, and updated the approach to ensure fiscal soundness by applying a surcharge to all policyholders ($25 for a primary residence and $250 for all others) (FEMA, 2018c).

3.2 Current Program Status

The National Flood Insurance Program is currently managed by the Federal Emergency Management Administration (FEMA), and is the primary provider of flood insurance coverage in the U.S. The NFIP provides nearly $1.28 trillion in coverage for over 5 million residential policies, $66 billion in coverage for non-residential properties, and collects about $3.5 million in annual premiums (Horn & Webel, 2018). Over its lifetime, the NFIP has evolved to have three main objectives: to provide flood insurance, to improve floodplain management, and to develop maps of flood hazard zones. While their results from selling insurance are easily measured in their financial outcome, the impacts of their other functions are harder to measure and see. The NFIP operates so that in years of multiple catastrophic disasters they are able to borrow from the Treasury to cover the gap between claims paid and premiums collected. However, over time the NFIP's debts have increased sharply, and with projected total claims of $9.7 billion for the 2017 hurricane season, Congress had to cancel $16 billion of NFIP debt in order for the program to pay its claims; thus making the cancelled debt a non-transparent, liability for general taxpayers, and as such a subsidy (Horn & Webel, 2018). The NFIP is currently operating on short-term reauthorization until May 31st, 2019 (FEMA, 2018a). A bill for long term reauthorization (H.R. 2874) passed the House in November 2017, however three bills (S. 1313, S. 1368, S. 1571) have been introduced to the Senate but none have been acted on by the full senate (Horn & Webel, 2018). All four of these bills contain various provisions to support the emergence of private flood insurance.

According to FEMA, the NFIP is currently focused on "implementing recent law by adjusting premium increases, issuing new rates and map updates, supporting mitigation and ensuring advocacy to connect policyholders with the information they need to better understand the program" (FEMA, 2018c).

3.3 Coverage and Rating

Flood coverage through the NFIP is available to anyone in a participating community, and purchase is generally voluntary except for those in Special Flood Hazard Areas (SFHA). In order to be eligible to participate, communities must adopt specific land use and building code standards. Coverage limits are relatively low, notably for non-residential properties or properties in high-cost areas and can be seen outlined in detail in Table 1. There is a mandatory purchase requirement that dictates property owners within SFHAs purchase coverage as a condition for any mortgage made, guaranteed, or purchased by any federal agency, federally regulated lending institution, or government sponsored enterprise (Horn & Webel, 2018). To comply with this mandate, coverage must be purchased through the NFIP or private insurer coverage must be at least as broad as the coverage of the NFIP. This mandatory purchase requirement is not enforced by FEMA but rather by lenders, and lenders can be fined up to $2,000 for each instance of noncompliance (Horn & Webel, 2018). Additionally, property owners who do not obtain insurance when required are not eligible for certain types of disaster relief after a flood. Beyond this legal requirement, some lenders are requiring borrowers outside of SFHAs to purchase flood insurance as well in order to financially secure the property.

Once a community joins the National Flood Insurance Program, a study is completed to issue a Flood Insurance Rate Map (FIRM) that is based on the community's flood risk and outlines the special hazard areas and other applicable risk premium zones. An example of a FIRM can be seen in Figure 2, and additional information about FIRM maps and flood hazard zone ratings can be found in Appendix A. The NFIP rates policies in different ways dependent upon whether a FIRM has been issued for the community. All buildings constructed after a FIRM has been issued are charged full-risk, actuarially fair premiums that include the full range of loss potential including catastrophic losses; if the new constructions are in compliance with floodplain management ordinances, the premium should be reasonable and affordable (Hayes & Neal, 2012). Additionally, this enhances the NFIP goal of discouraging building in areas known to have a high flood risk because the full-risk premiums for coverage would be unaffordable. In addition to new constructions, all buildings found to be outside of Special Flood Hazard Areas are charged full-risk premiums since the risk is low the premiums are low as well (Hayes & Neal, 2012). Buildings in SFHAs that were constructed before the development of the FIRM are charged discounted, or subsidized, premiums, since their full-risk premiums would be extremely high (Hayes & Neal, 2012). It is notable that the NFIP is not provided funds to offset the subsidized and discounted premiums which has contributed to their need to borrow from the U.S. Treasury to pay NFIP Claims (Horn & Webel, 2018).

The justification for subsidized premiums aligns closely with the goals of the NFIP. Lowering premiums for existing structures made it easier for communities to join the NFIP thereby increasing the number of communities with sound floodplain management and reducing the nation's flood risk exposure. Reasonable premiums also increase the likelihood that a property owner purchases insurance and at least partially fund their own recovery from flood damage which is preferable to disaster relief coming solely from taxpayer funding. Too high premiums for flood insurance could also cause the abandonment of economically viable buildings which does not support the goals of the NFIP. An assessment by the NFIP found that if charged full-risk rates subsidized policies would pay on average two and a half times their current premium, and if the subsidy was eliminated and full-risk rates were charged for all NFIP policies, the aggregate premium for the program would increase between 50%-75% (Hayes & Neal, 2012).

In addition to subsidized premiums, NFIP policyholders can receive reduced rates through the Community Rating System (CRS). The purpose of the CRS is to encourage floodplain management activities that exceed the NFIP minimum standards, and depending on the extent of participation, policyholder's premiums can be reduced by as much as 45% (FEMA, 2018b). Beyond just the reduction in insurance premiums, FEMA claims that CRS floodplain management activities "enhance public safety, reduce damage to property and public infrastructure, avoid economic disruption and losses, reduce human suffering, and protect the environment"(FEMA, 2018b). Currently, nearly 3.6 million policyholders in 1,444 communities participate in the community rating system; CRS communities represent only 5% of the 22,000 communities participating in the NFIP, but due to the increase in affordability that the CRS provides, 69% of all flood insurance policies are written in CRS communities (FEMA, 2017). Communities are classified based on their participation in 19 credible activities that fall into 4 categories: public information, mapping and regulations, flood damage reduction, and warning and response (FEMA, 2017) Communities also have access to technical assistance for designing and implementing some activities at no charge (FEMA, 2018b). Participation in this program provides communities an additional incentive to improve and maintain their floodplain management program and can even get them to qualify for other federal assistance programs (FEMA, 2018b). The community rating system is a way for the NFIP to offer direct premium reductions on policies where there is an active effort to reduce risk exposure.

NFIP Maximum Available Coverage Limits

	Contents	Building Coverage
Single Family Homes	$100,000	$250,000
Other Residential Buildings	$500,000	$100,000
Non-Residential Buildings	$500,000	$500,000

Table 1 (Horn & Webel, 2018)

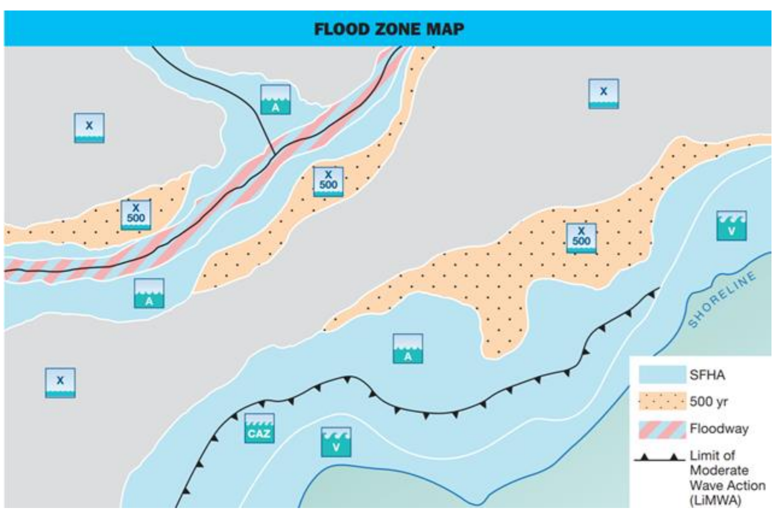

Figure 2 (FEMA, 2018d)

3.4 Private Market Involvement

Although private insurers have taken on minimal flood risk since initially withdrawing from the market, they have been involved with the National Flood Insurance Program through both the administration of policies and reinsurance.

3.4.1 Administration of Policies

The main way in which the private market is directly involved with the NFIP is through the administration of policies. While FEMA provides management to the NFIP and is ultimately the risk bearer, the day-to-day operations of the NFIP are handled by private companies. This includes all aspects of the insurance process including marketing, selling and writing policies, and all aspects of the claim process. There are two types of arrangements that the NFIP has with private insurers, and in both, the NFIP retains the financial risk of paying the claims and the policy terms and premiums are the same. The first is the Direct Servicing Agent (DSA) in which the private insurer acts as a private contractor selling NFIP policies on behalf of FEMA to individuals seeking to purchase coverage directly from the NFIP (Horn & Webel, 2018).

The second arrangement is the Write-Your-Own (WYO) program. Through this program, companies are paid to write and service the standard NFIP flood insurance policies in their own name. The WYO program has three main goals: increase the NFIP policy base and geographic distribution, improve service to NFIP policyholders, and to provide the insurance industry with direct operating experience with flood insurance (FEMA, 2019c). About 12% of the NFIP policy portfolio is managed through the DSA program with the remaining 88% administered through the 60 companies participating in the WYO program

(FEMA, 2019c) (Horn & Webel, 2018). The companies participating in the WYO program as of August 2018 can be found in Appendix B.

3.4.2 Reinsurance

The 2014 Homeowner Flood Insurance Affordability Act enabled the private market to begin bearing a portion of the NFIP flood risk by giving FEMA the authority to secure reinsurance for the NFIP from private reinsures as well as the capital market (Horn & Webel, 2018). There were a few motives for implementing this change, the most notable being that it reduces the chance that FEMA will need to borrow from the treasury to pay claims. Additionally, it allows FEMA to price policies more efficiently because they can factor what they are paying in reinsurance premiums into their own pricing model. The main benefit of reinsurance, for the NFIP but also in general, is that it creates stability and reduces the volatility of losses over time especially when potentially extreme events are involved. For the past three years, FEMA has purchased reinsurance to cover losses from individual flood events, as opposed to aggregate losses, and the structure of these various reinsurance agreements can be seen in Figure 3. FEMA contracted with Guy Carpenter and Company, a subsidiary of Marsh & McLennan Companies to provide broker services to secure reinsurance placement, and they contracted with Aon for financial advisory throughout the reinsurance process (FEMA, 2019a). The 2019 agreement for $1.32 billion in reinsurance coverage is composed of contracts with 28 private reinsurers who can be found listed in Appendix C. In August 2018, FEMA transferred additional NFIP risk to private markets by securing $500 million of reinsurance from the capital markets through the issuance of the FloodSmart Re. catastrophe bond (Artemis, 2018). The transaction was facilitated with assistance from Hannover Re through the Hannover Re Designated Activity Company and is backed by more than 35 insurance-linked securities investors. It is designed as a three-year bond term running from August 1st, 2018 to July 31st, 2021 (Artemis, 2018). Three of the proposed bills currently in congress require or encourage the NFIP to continue to transfer risk to the private reinsurance market (Horn & Webel, 2018).

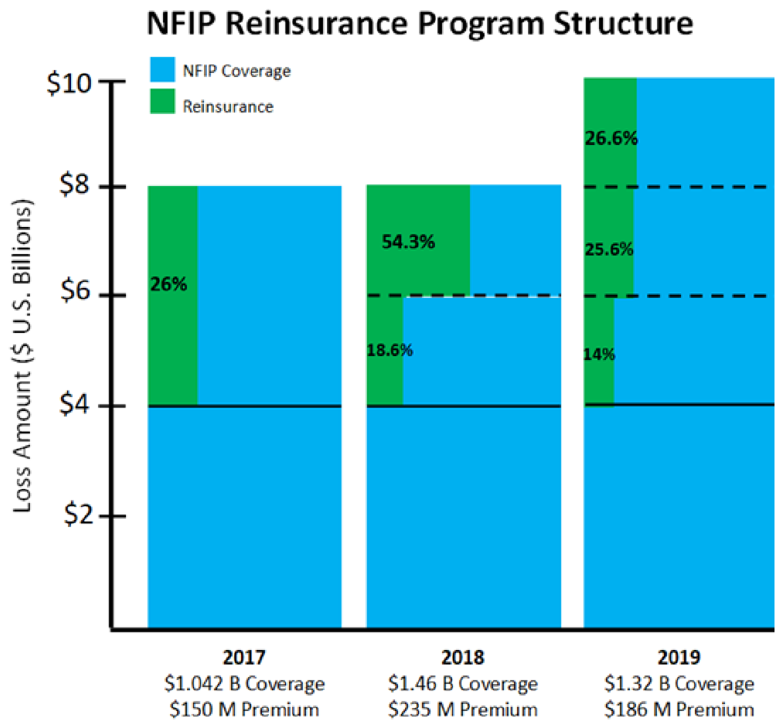

Figure 3 (FEMA, 2019a)

4 Privatization of Flood Insurance

4.1 Current Private Market Flood Insurance

In addition to the NFIP, there are a few private companies that have started to break into the market in recent years and currently offer flood insurance coverage to consumers. Private company policies generally provide commercial coverage or coverage beyond the NFIP coverage limits. Additionally, the private market tends to focus on high-value properties which have higher premiums which therefore justify the extra expenses of flood underwriting (Horn & Webel, 2018). Private flood insurance has shown consistent growth over recent years but still only makes up 3-4% of the total market. Most private flood coverage is written by surplus lines carriers however some admitted carriers have begun to offer it has well. The most recent study regarding private flood insurance was conducted in 2017 by the National Association of Insurance Commissioners (NAIC) and results were published in June 2018. NAIC reported $630 million in private market flood premiums for 2017, up from the $412 million written in 2016, but this is still a fraction of the NFIP premiums of $3.5 billion (Carrier Management, 2018). Commercial lines still represent the majority of business written, with approximately 64% of the market down from 66% in 2016. This is due to a $104 million increase in residential private flood coverage largely driven by Assurant's entrance to the market and their $88.2 million written in new residential flood insurance (Carrier Management, 2018). Other carriers that contributed to a significant portion of the 2017 market growth include ZurichRe, FM Global, Berkshire Hathaway, and Liberty Mutual (Carrier Management, 2018). The top 8 carriers of both private commercial and residential flood as well as their 2017 direct premiums written are outlined in Figures 4 and 5 below.

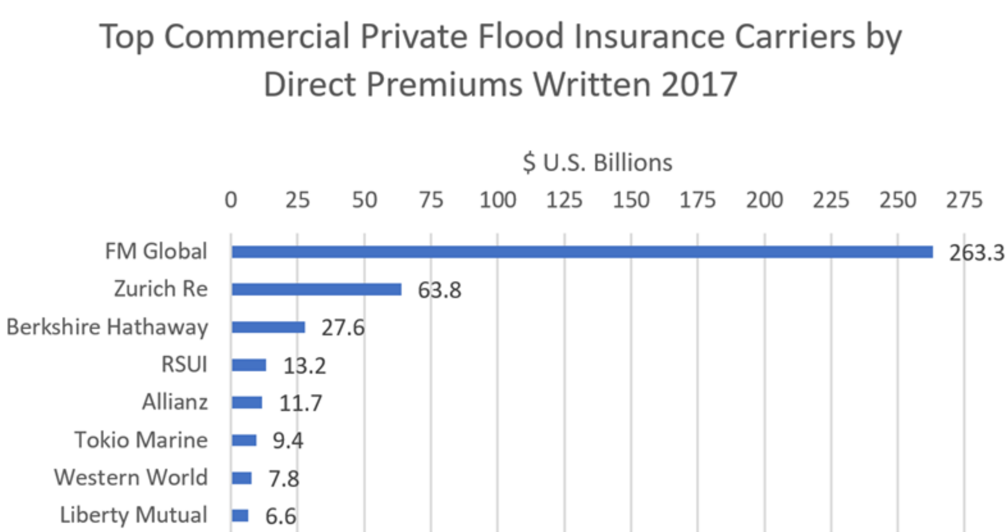

Figure 4 (Carrier Management, 2018)

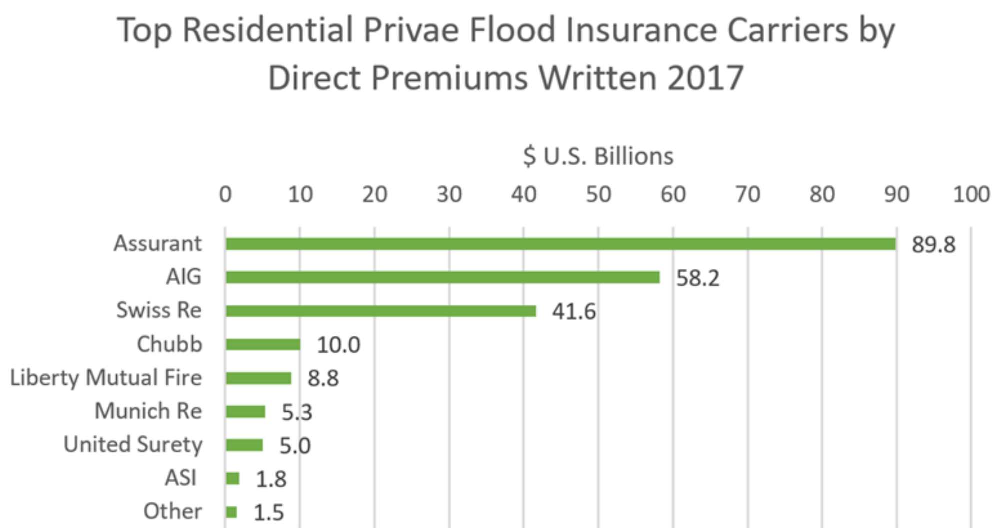

Figure 5 (Carrier Management, 2018)

4.2 Issues and Barriers to Entry

Private insurers have made clear their interest to enter more prominently into to the flood insurance market, however in order for them to do so, there are various obstacles and difficulties that they will have to overcome. Many relate to the NFIP and the federal regulation of flood insurance but overcoming the rating problem in order to make flood insurance a profitable operation is a concern as well.

4.2.1 Regulation

Currently, the NFIP allows for flood insurance purchased under the mandatory purchase requirement to be purchased through a private insurer, given that the coverage is "at least as broad as" the coverage available through the NFIP (Horn & Webel, 2018). The difficulty in this is that no entity has been assigned the task of evaluating whether specific policies meet this standard, and the criteria to be used in this assessment remain undefined. Two of the proposed congressional bills include provisions to remove this language and instead allow for any private insurance that is in compliance with individual state laws and regulations to be accepted in fulfilling the mandatory purchase requirement (Horn & Webel, 2018).

Another reason that private insurers continue to have limited involvement in assuming flood risk is due to the “non-compete” clause that previously existed in the standard contracts between the NFIP and Write Your Own (WYO) carriers (Horn & Webel, 2018). This clause was recently amended for the 2019 fiscal year to allow WYO carriers to also offer their own flood coverage provided that they ensure it remains entirely separate from their NFIP WYO business. This includes ensuring that all communication regarding the private policies clearly indicates that it is not supported by the NFIP, FEMA, or the Federal Government in any way, and that all data related to the carrier’s arrangement with the NFIP not be used to support their non-NFIP flood insurance lines (FEMA, 2018e).

Private insurers are also concerned about the uncertainty of state regulation as it relates to flood insurance. Most other insurance markets are regulated at the state level, so as private sector involvement in the flood market continues to grow, it is reasonable to assume that state regulator’s involvement in the flood market will grow as well. This will likely add complexity and additional costs to insurers, and the uncertainty surrounding it has contributed to the hesitation of private insurers to enter the market. Consumer protections will also vary if private policies are regulated at the state level. The language in private flood policies is not standardized and has not been tested in court in the same way as other coverages, such as homeowners, have been. Therefore, there may be a greater variability in the outcome of claims for insurers, as well as for consumers, in the early years of private flood insurance coverage. However, regulation at a state level could provide benefits to the market as well through the development of state-specific insurance solutions that better suit local social and economic conditions (U.S. Department of Homeland Security, 2015).

4.2.2 Rating

In the absence of any regulation that forces private coverage, the private insurance market only underwrites risks that can reasonably be expected to result in a profitable line of business. Shortcomings in adequate ratemaking are what made flood insurance unprofitable, leading to the initial withdrawal of insurers from this market. Proper ratemaking is easier said than done, and there are a number of challenges that private insurers will have to overcome before beginning to write profitable flood policies.

4.2.2.1 An Evolving Risk

One reason that flood risk is especially difficult to cover is because it is a widespread and dynamic risk. The entire country is exposed to flood risk, and the flood risk in a particular location transitions over time, due to new development, changes in flood management infrastructure, and environmental changes.

Flooding typically falls into one of three categories: coastal surge flood, fluvial, and pluvial. Coastal flood occurs in areas that lie on the coast of a large body of water and is the result of extreme tidal conditions caused by severe weather. Storm surge is the most common form of coastal flooding. It occurs when high winds from hurricanes and other storms push water onshore (Maddox, 2014). Fluvial, or riverine flooding, occurs when excessive rainfall over an extended period of time causes a river to exceed its capacity; it can also be caused by heavy snow melt and ice jams (Maddox, 2014). The damage from this type of flooding can be widespread as the overflow in one area affects smaller rivers downstream and can cause dams and dikes to break. According to FEMA, fluvial flooding is the most common type of flood event (Maddox, 2014). The third type of flooding, pluvial or surface flooding, occurs when heavy rainfall creates a flooding event that is independent of an overflowing body of water, although it usually happens in conjunction with coastal or fluvial flooding (Maddox, 2014). This type of flooding typically happens when drainage systems become overwhelmed or when land is so saturated it is unable to absorb runoff. None of these types of flooding are covered under typical homeowners or property insurance coverages but would be covered under a flood insurance policy.

Exposure to all three types of flooding changes over time because of weather patterns, erosion, and new development. According to the 2017 Climate Science Special Report, many parts of the U.S. have experienced an increase in flooding over the last 50 years while others have experienced a decrease (Union of Concerned Scientists, 2018). Climate change is one of the biggest drivers currently altering flood risk around the world. Multiple studies have shown that extreme precipitation events have become more frequent and more intense in parts of the United States since the early 1990s; heavy rainfall events are one of the primary contributors to flooding, and the warming atmosphere is causing these events to occur more frequently (Union of Concerned Scientists, 2018). Trends regarding rain and flooding in the U.S. can be found illustrated in Figure 6. The US National Weather Service recorded 10 rare rain events that led to flooding between May 2015 and August 2016 even though similar events were projected to occur once every 500 years (Union of Concerned Scientists, 2018). An increase in the frequency and severity of high precipitation events increases the likelihood and impact of all 3 types of flooding.

Land use changes including construction in floodplains, increased use of impermeable surfaces such as asphalt, the removal of wetlands and river bank vegetation, deterioration of water-management infrastructure, and the building of dams, levees, or channels can alter the ability of land to accommodate heavy precipitation and can change the natural flow of rivers and streams which in turn increases the potential for flooding. A study of the Mississippi River found that the increase in flooding over the past 150 years cannot be explained by precipitation patterns alone and that river engineering and agricultural expansion are responsible for up to 75% of the increased flood risk (Union of Concerned Scientists, 2018). Additionally, an analysis of Harris County, Texas noted rapid suburban development as reducing the land's natural drainage and contributing to increased flood risk during events such as Hurricane Harvey (Union of Concerned Scientists, 2018). The increase in wildfires from climate and land use changes also has an impact on flooding as less water is retained and erosion increases.

The impact of flooding events is enhanced by the movement of people to hurricane and flood prone areas. Historically, people sought to settle near the coast and along waterways, and those settlements have continued to grow into towns and cities over time. From 1980 to 2017, there was an increase of 95 people per square mile, more than double, in counties along the U.S. shoreline that experienced hurricane-strength winds from Florence in September 2018 (Dapena, 2018). Overall, areas most vulnerable to hurricane strikes, namely counties along the Gulf and East coast, had an increase of 160 people per square mile, compared to an increase of 26 people per square mile in the mainland over the same period (Dapena, 2018). This increase in population and exposure in hurricane and flood prone areas is a significant driver of the increasing cost of storms and outlines yet another way that flood risk is changing.

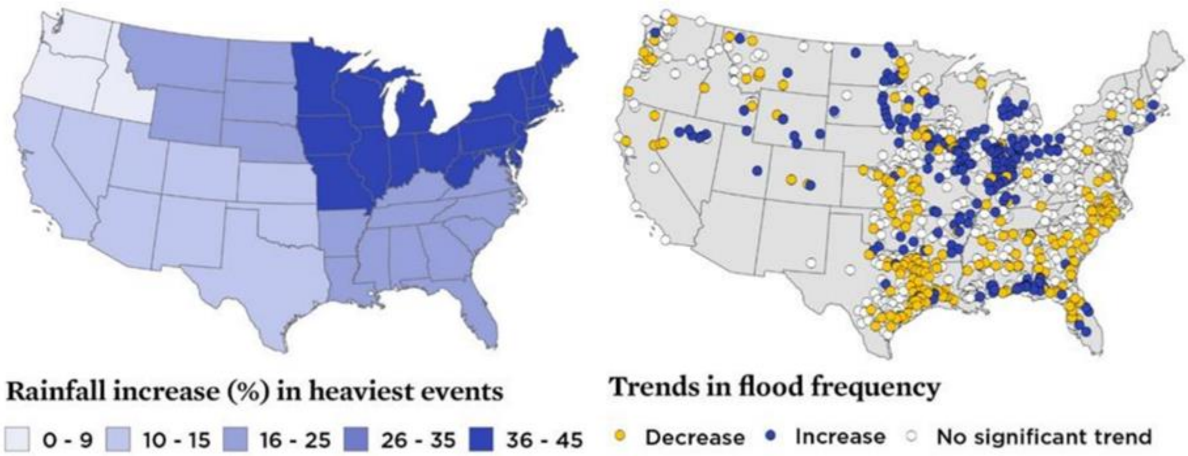

Figure 6 (Union of Concerned Scientists, 2018)

4.2.2.1.1 A Case Study of North Carolina

In order to see the evolving nature of flood risk, we can take a closer look at North Carolina and the impact of Hurricanes Hazel and Florence on the state. These two storms lend themselves to a natural comparison because of their nearly identical landfall locations and paths across the state. Hurricane Hazel made landfall as a category 4 hurricane near Calabash, NC on October 15th, 1954 (Storm Events Database). Hurricane Florence made landfall as a category 1 hurricane near Wrightsville Beach, NC, about 50 miles northeast of Calabash, on September 14th, 2018 (Storm Events Database).

At the time of its occurrence, Hurricane Hazel was considered the most destructive hurricane to ever affect the state; coastal winds were estimated as high as 150 MPH and storm surge reached 12-18+ feet (Storm Events Database). The storm caused 19 fatalities in North Carolina, destroyed or damaged over 50,000 homes and caused $1.48 billion in total damage to the state (inflated to 2019 dollars) ("Storms to Life" Report, 2010). Current catastrophe models estimate that if Hurricane Hazel were to strike in October 2018, total damage would reach $4.7 billion. The $3.22 billion difference in damages between when the storm actually occurred and the losses if the same storm were to occur today, clearly shows the increase in financial impact that results from the continuing development and redistribution of land use in hurricane prone areas.

Hurricane Florence, although just a Category 1 storm at landfall, had an even greater impact on the state. With wind speeds near 90 MPH and storm surge of 10 feet, Florence resulted in 39 deaths in NC and caused a total of $23 billion in damage ("Storms to Life" Report, 2018). Although Hazel was a more powerful and intense storm, Florence had a bigger financial impact on the state. This is partly because Florence was more spread out and affected a larger portion of the state, but also because of the movement of the storms after landfall. Hazel continued to move at around 55 MPH, but Florence only traveled forward at a speed of around 5 MPH (Storm Events Database). Because Florence sat and hovered, the state was exposed to its destructive elements for a longer period of time which resulted in more damages. Additionally, Florence brought significantly more rain than did Hazel resulting in substantially more flooding in addition to wind damages.

The difference in the nature of these storms explicitly demonstrates the evolution of catastrophic events over time due to climate change as well as other factors. On average, hurricanes in particular are becoming slower moving and wetter events therefore causing more damage from extreme flooding and storm duration.

4.2.2.2 FEMA Flood Maps and Data

In addition to the evolving nature of flood risk causing rating difficulties, insurers currently do not have access to the information necessary to adequately evaluate flood risk across the United States which is an important aspect of the ratemaking process.

FEMA produces the Flood Insurance Rate Maps (FIRMs) that are used by the NFIP to rate their flood insurance policies, although the accuracy and usefulness of these maps have been under scrutiny from the private insurance market. FIRM maps are used in over 22,000 communities and FEMA has spent $200 million in recent years to update the maps (Adriano, 2018). However, a February 2018 publication by the *Environmental Research Letters* journal reported that more than 40 million Americans are exposed to high flood risk at the 100-year-flood or 1% level which is roughly three times more than the risk suggested by FEMA's flood maps (Adriano, 2018). Even with FEMA's recent spending on mapping updates, in 2017 only 42% of maps were up to date with some of those still in use dating as far back as the 1970s (Adriano, 2018). While FEMA attempts to keep track of land use and gradient changes through letters of map revisions, FEMA flood maps have been criticized for not considering the evolving nature of flood risk, most notably climate change, previously discussed.

This does not necessarily mean that FEMA maps are without value. It is important to remember that these maps are created for purposes beyond just that of insurance pricing; they are also used in the development of zoning and land usage laws. Additionally, the maps were created specifically for the use by the NFIP in policy rating and the goals of the NFIP do not always align with the goals of private insurers; the NFIP is charged with making flood coverage available to those who need it at an affordable price while private insurers are focused on making a profit. Because of this discrepancy, the risk rating that FEMA gives a property may not always align with the risk rating that the private market would assign it. This means that although the FIRM maps are accurate and useful to FEMA and the NFIP, they are not sufficient for use by the private market to rate flood insurance policies. The private market will therefore have to develop their own flood risk evaluation tools and models for use in the policy rating process which will be discussed in section 4.2.3.1.

The private market needs an extensive amount of data regarding both past flooding events and resulting claims in order to develop these models as well as for use in other steps of the ratemaking process. Since flood insurance has not been offered by private companies for so long, they are facing a severe lack of this necessary data. NFIP data on flood losses and claims is currently unavailable to the private market. Increasing access to past NFIP data would allow insurers to better estimate future losses and price their premiums which ultimately will determine whether they are willing to enter the market and which properties they might be willing to insure. However, the Privacy Act of 1974 prohibits FEMA from releasing policy and claims information that contains personally identifiable information, so FEMA would have to address these privacy concerns in order to be able to provide property level information to insurers (Horn & Webel, 2018). The proposed congressional bills include terms on making claims data available: one would require FEMA to make all NFIP claims data publicly available in a form that conceals personal information, another would authorize FEMA to sell or license individual claims data while requiring aggregate claims data be made available (Horn & Webel, 2018).

4.2.2.3 The Subsidy Problem

The subsidy problem is often seen as one of the largest barriers to private sector involvement in flood insurance. Law currently mandates that a portion of the cost of flood insurance for properties in high risk flood areas be subsidized. In order for private insurers to take on a risk, they must charge an "actuarially fair" rate that adequately reflects the risk that they are acquiring. Private insurers also require that their rates include a profitable return on capital as well; this means that even rates that are actuarially sound from an NFIP perspective may still be underpriced from the perspective of private insurers.

Should the NFIP continue to operate and private insurers enter the market as direct competitors, the private market will not be able to compete with the NFIP subsidized rates and will therefore be unable to write policies in those locations. With around 20% of NFIP policies receiving some sort of subsidy, there is a large portion of the market that is automatically unavailable for private insurers to access (FEMA, 2014). However, private companies have already found niches where they believe they will be able to underprice the NFIP. With the total extent of NFIP subsidization not historically tracked, it is difficult to quantify how NFIP and private insurance rates would compare. Milliman and KatRisk attempted to answer this question by looking at the premiums for single family homes in Louisiana, Texas, and Florida. Their modeling suggests that 77% of single-family homes in Florida, 69% in Louisiana, and 92% in Texas would pay less under a private policy than under the NFIP; however, 14% in Florida, 21% in Louisiana, and 5% in Texas would pay over twice as much (Horn & Webel, 2018).

Through the Biggert Waters Flood insurance Reform Act of 2012 and the Homeowner Flood Insurance Affordability Act of 2014, FEMA is already actively working to reform their rating approach and move towards a more risk-based pricing structure, although they are still faced with restrictions placed on their annual premium rate increases. The move to risk-based pricing will encourage the growth of private insurer involvement in the primary flood insurance market because they will be able to compete with the NFIP in more areas. This move will lead to higher rates for households in flood prone areas which aligns with the NFIP goals of discouraging building in those places.

An associated issue is that of continuous coverage. Under existing law, if an NFIP policyholder allows their policy to lapse, any subsidy that they received is eliminated immediately. Unless legislation is changed to allow for private insurance to count as continuous coverage, policyholders may be reluctant to purchase private insurance if it meant that they would lose their subsidy should they ever decide to return to NFIP coverage. With NFIP subsidized rates increasing to better reflect risk, this barrier to entry may resolve on its own.

4.2.2.4 Rating Theories

Even with the other barriers to entry removed, there is still the need for private insurers to determine how they will rate their flood insurance policies. The NFIP relies on the FIRM flood maps produced by FEMA for ratemaking purposes. Since profit making is not part of the NFIP's overall purpose, the maps they use for rating will not translate well to usage by private insurers for rating policies; additionally, it has been established that the NFIP rating structure would not be profitable since the NFIP is heavily in debt[1]; although, some of the debt is attributable to the subsidy problem previously discussed. Quantifying risk is the first step in the ratemaking process. Since insurers lack faith in FEMA's maps to accurately do this, they first need to come up with an alternative method to evaluate flood risk which will be discussed in section 4.2.3 and the accompanying subsections. Once they are satisfied that have been able to properly assess a property's flood risk, there are a few techniques that they have been proposed regarding how insurers could handle pricing flood insurance policies.

4.2.2.4.1 Multi-Peril Ratemaking

The first rating technique would prove useful if insurers were to offer flood coverage as a part of homeowner's policies, and it involves including flooding as a peril in property

[1] NFIP current debt is approximately $20.5 Billion after subtracting the $16 billion that was waived after 2017-2018 storms, and $4.2 billion in interest has been paid since Hurricane Katrina in 2005. (FEMA, 2019b)

insurance multiperil ratemaking. Decomposing risks by peril is not a unique or new idea and is commonly used in homeowner's insurance rating. Rating by peril is intuitively appealing because the predictors that are useful in predicting one peril may not predict well for others. Current multi-peril rating practice is based on modeling each peril in isolation of the others. However, the problem with rating in this way is that it assumes that the perils are independent although past studies have demonstrated statistically significant dependence among perils (Frees, Meyers, & Cummings, 2012). This can have major implications when discussing flood risk since floods often occur in conjunction with other perils: hurricanes bring flooding and wind, thunderstorms bear lightning and heavy rains. Including the relationships between perils in multi-peril models has the potential to allow insurers to more accurately model true risks and therefore develop adequate premiums that are reflective of that risk. It has been proposed to include the dependency of perils through the usage of copulas in a generalized linear model to create a multivariate framework for pricing (Yang & Shi, 2018). By using this framework on perils that are correlated, the information on one peril will aid in learning about the other perils. It is also important to include the dependence between risks in multi-peril models because risk dependence has important implications for risk aggregation and risk margin analysis (Yang & Shi, 2018). The availability of longitudinal data also makes this model for multi-peril rating appealing to insurers. Longitudinal data is repeated measures of the same subject; in this context, looking at past loss experience for a singular property. This not only allows insurers to incorporate experience rating through repeated observations but allows them to incorporate the claim history not only for the peril being priced but other correlated perils as well.

Although applying a multi-peril model to homeowners insurance is intuitively plausible, not all insurers will want to use this complex model. Pricing by peril requires more efforts on data collection and model building. In the end, customers are charged a single price for homeowners insurance meaning that decomposition by peril may not be necessary or worth the added cost. Additionally, like all complex models, there is the potential that models with extra parameters could lead to overfitting and overall poor prediction. In order to implement this multivariate framework for multi-peril models, extensive past loss data is necessary, and as previously discussed, there is a lack of this data in the private market and obtaining it from FEMA presents its own challenges.

4.2.2.4.2 Base Premium with Simulated Catastrophe Adjustment

It has also been suggested that standard property insurance ratemaking techniques with the addition of a premium adjustment for long-term catastrophic loss exposure based on expected losses from simulation tools (also known as "cat models") would work well for flood insurance ratemaking. This rating procedure would easily apply to independent flood insurance products; simulated expected loss could also prove to be a useful addition in multi-peril ratemaking for policies covering a variety of perils including flood. This technique lends itself well to ratemaking for flood risk due to the variety of flood risk that exists and its catastrophic nature. The base premium rate constructed by the insurer would reflect the sustained flood risk that a property faces: property that has never flooded before would have a low base rate while properties that flood regularly from typical rainfall would start with a higher base rate. This rate would then be adjusted based on the results from catastrophic scenario simulations. The simulations would account for the flood risk associated with higher intensity, lower frequency extreme weather events.

While this rating technique seems significantly more straightforward than multi-peril ratemaking, it is not without faults of its own. It is of limited usefulness to products other than standalone flood insurance; it is likely that flood insurance will be sold as an endorsement to or as a covered peril in more comprehensive property insurance coverages. Additionally, insurers face the difficulty of determining how to develop the base rate for a property. With no past claims data available to derive these rates from, insurers would have to construct their own process to evaluate base flood risk which takes time and could be costly. This is made even more difficult due to the previously discussed evolving nature of flood risk which insurers may need to account for in the development of a base rate. Furthermore, in order to employ the use of catastrophe models in flood ratemaking, the models have to first be produced as well as tested extensively. While these models exist for and are used in the ratemaking of other insured perils, the development of catastrophe models for flood risk has proved to be difficult. Catastrophe models in general as well as those specific to floods are discussed in more detail in section 4.2.3.1.

4.2.2.4.3 Community Rating

Insurers may also consider setting premiums for flood insurance based on a community rating system. They could copy the system that the NFIP uses where policyholders receive a discount in communities with strong floodplain management systems in place. However, unlike the NFIP, private insurers would be not be able to provide assistance to communities to put these techniques in place. Without assistance, many communities would remain unable to build the necessary infrastructure to manage flood risk and therefore would not be able to receive the community rated premium reduction resulting in flood coverage remaining unaffordable for a large portion of property owners. While this type of community rating works well when an agency like FEMA is in place to support it, it would likely not transfer well to the private market.

The private market could consider applying a community rating system similar to what is often used in health insurance to their flood insurance products. In a health insurance context, community rating refers to a rating system that requires all insureds in the same geographical area to pay the same premiums, regardless of their health status (Community Rating, n.d.). While community rating of a similar format is not currently used for any property insurance, it may be useful for flood rating. This would involve insurers evaluating the risk for each property in the community to establish an aggregate risk level. The premium for this aggregate risk would then be divided more evenly between all participants with less emphasis on their individual risk level: high-risk properties would pay slightly less than their risk-reflective rate while low-risk properties would pay slightly more. Community rating is beneficial in that it would ensure private flood insurance is still affordable for high-risk individuals.

Although this rating system includes a type of policy subsidy, insurers will not face the same financial risk that the NFIP faces since they will be collecting adequate premiums overall (amounts that in aggregate cover the risk underwritten). It can be argued that a policy rated in this way would be difficult to sell as low-risk individuals do not want to subsidize the rates for high-risk individuals. It is true that individuals likely do not want to subsidize the rates for property owners on the other side of the country, however, they may be more inclined to subsidize the rates for their neighbors. After an intense flooding event, the resilience of a community is greatly impacted by the ability of individuals to rebuild. Lower-risk property owners may be willing to subsidize a portion of their higher-risk neighbors' rates since they arguably benefit from the insurance, both before and after a loss occurs. A lot of this benefit comes in the form of mitigation funding and disaster relief from FEMA; communities that cooperate with FEMA are eligible for flood mitigation grants and disaster relief. Selling policies rated in this way will be difficult as low-risk property owners may have trouble seeing the benefit that they would be receiving.

In order for community rating of flood insurance to work, adequate consumer participation is of utmost importance; this rating system may not be viable unless some variation of a mandatory purchase requirement is in place. Implementation of this rating system would prove difficult as insurers would be required to come up with ways to define or group communities for the rating process as well as develop the tools necessary to evaluate flood risk. It may also be too difficult for individual insurers to gain enough exposure in a singular community to implement this system, and even if they are able to, the risk they would be taking on would be poorly diversified. In order for this rating system to work, extensive collaboration, or even a pooling system, between private insurers is necessary, and with each insurer having their own risk evaluation techniques and individual risk appetite, this seems nearly impossible. While this system would solve the issue of private market flood policies being unaffordable for high-risk properties, its complexities would require the continuation of a governing body, such as the NFIP, to oversee private company collaboration.

4.2.3 Evaluating and Managing Catastrophic Risk

The frequency and severity of flooding events easily classify it as a catastrophic risk. In order for the private market to be willing to offer flood insurance, they need to be able to ensure that their rates will result in a profitable product. This requires insurers have a complete and detailed understanding of the risk they are taking on so that they are able to develop a rate that accurately reflects this risk in addition to having access to the financial instruments necessary to manage the risk. Since FEMA's flood maps are not appropriate for use by the private market for this function, private insurers are faced with having to develop their own risk assessment tools. While the creation of applicable flood maps would assist insurers in risk evaluation, due to the complex nature of flood risk, it is universally accepted that the use of catastrophe models is necessary in order to produce and accurate assessment of flood risk. Catastrophe models are currently widely used by insurers for pricing, risk selection and underwriting, loss mitigation activities, reinsurance decision making and overall portfolio management for a variety of catastrophic perils (Clark, 2002).

4.2.3.1 Flood Catastrophe Models

Catastrophe models for flood risk are currently being developed by a variety of modeling companies, but they are not yet widely employed by private insurers for use in the ratemaking process. In general, catastrophe models work by combining mathematical representations of the natural occurrence patterns and characteristics of catastrophes and information on property values, construction types, and occupancy class to provide information to insurers about the potential for losses before they occur (Clark, 2002). Insurers use catastrophe modeling to anticipate the likelihood and severity of potential future events so that they can appropriately prepare for the financial impact. A basic example of a flood catastrophe model along with a discussion of applications can be found in Appendix D.

In theory, catastrophe models should work well for evaluating flood risk since the lack of past data is a huge barrier to current flood rating; models are based on simulations created by analyzing the characteristics of past and potential events rather than fixating on analysis of past loss history. A variety of companies have produced catastrophe models for flood and are marketing them to insurers, but none of these producers have come forth to provide data or examples of the accuracy of their models despite marketing claims of their credibility. Their hesitancy to discuss model specifics could be due to a desire to keep product information proprietary; however, it could also be due to a lack of relevant loss data to use for model validation purposes causing modelers to be unsure as to the accuracy of their product. The flood events over the last few years are helping insurers, reinsurers, and modeling companies to be able to validate their models against real losses which in conjunction with obtaining more comprehensive data will aid in improving model accuracy.

Despite the complexity of flood risk, it is arguably more definable than hurricane and earthquake risk, and these are already being rated largely based on loss estimates from catastrophe models. Wind is a chaotic process; in a hurricane one house can be hit by strong gusts while the one beside it is spared. Flooding, on the other hand has a lower level of intrinsic variability because flood heights are relatively consistent from one patch of land to the next. The difficulty in developing flood models comes from not currently having the necessary data. There are three areas in which information is still needed in order to model flooding effectively: property elevation, existence of flood defenses, and information on what is happening below the ground floor (Is there a basement? What is it used for? Are expensive items stored there?) (Howard, 2019).

Many of the current producers of flood catastrophe models also offer other widely used catastrophe models as well: Milliman, AIR Worldwide, KatRisk, and Risk Management Solutions (RMS). As the demand for this product is still developing, there are many other companies vying for a spot as one of the first to develop the best flood model, including new companies focused solely on modeling flood risk. Almost all of the models differentiate between fluvial and pluvial flooding events. Many have integrated flood with existing hurricane and storm surge models to give a more comprehensive view of tropical storm impacts while also providing a model specific to inland flooding. Each company's product boasts unique features in simulation processes as well as output calculations as they try to stand out from their competitors. There are not currently any models that are seen as being better than the others since their accuracy is still under scrutiny and working to be improved. Industry professionals strongly believe that flooding is a definable peril and that the development of robust and accurate catastrophe models is inevitable (Howard, 2019).

4.2.3.2 Reinsurance

In addition to being able to evaluate the catastrophic nature of flood risk, private insurers need to ensure that there is an adequate appetite in the reinsurance market to assume a portion of the high severity risk that flood presents. The willingness of reinsurers to provide coverage to the NFIP in recent years is promising for the private market. If reinsurers are able to offer coverage to a program not focused on making a profit and riddled with adverse selection it can be assumed that they would be inclined to offer reinsurance for flood risk to private insurance companies as well.

Capital markets have also become increasingly interested in participating in the insurance industry, which can be specifically seen through the ability of FEMA to administer a catastrophe bond in 2018. Even if private insurers are unable to acquire reinsurance, they also have these alternative risk financing techniques available to them through the capital market. Private insurers should not be worried about the ability to obtain the proper instruments to help them manage high severity flood risk since alternative markets have already proven their interest and ability to assume this risk.

4.2.4 Adequate Consumer Participation

Many private insurers are concerned that there is not sufficient participation by consumers in the flood insurance market which is necessary for them to manage and diversify their risk exposure. Good risk assessment does not drive consumer behavior; even if insurers are able to create the necessary tools to accurately evaluate flood risk that doesn't mean consumers will be willing to purchase their flood insurance products. Even with effective ratemaking, the problem of adverse selection, which led to the creation of the NFIP in the first place, will continue to exist and create a vicious cycle. If only high-risk individuals are buying flood coverage, then rates overall will increase. This in turn decreases the number of individuals who decide to purchase coverage to where only those with extremely high loss potential are purchasing coverage which then furthers the issue of adverse selection.

The NFIP has always seen increasing the purchase of flood insurance policies as one of their objectives, and it was their motivation behind enacting the mandatory purchase requirement. Even with the mandatory purchase requirement in place, flood insurance participation rates have consistently remained low, although no official studies on compliance have been conducted since 2006 (Horn & Webel, 2018). Nationwide, the purchase rate in Special Flood Hazard Areas, the only areas where the mandatory purchase applies to a portion of the population, is only a little over 30%, and outside of SFHAs they are much lower (Kousky et al., 2018). However, as of February 2018, around 2 million households outside of mandatory purchase areas had voluntarily purchased coverage

(Kousky et al., 2018). Broad participation is necessary to limit adverse selection and maintain a sufficiently large and diverse risk pool, so many people believe that some form of a mandatory purchase requirement will likely remain in place. All proposed bills require a study to assess the compliance with the current mandatory purchase requirement (Horn & Webel, 2018).

In order to overcome adverse selection and ensure adequate market penetration, the discussion around flood insurance needs to change. It is necessary to shift consumer perception so that flood insurance is no longer seen as an added, unnecessary expense, but as an essential product that could have a substantial impact on financial status and quality of life should a loss event occur. Achieving this would require educating consumers to establish a more robust understanding of the risk they inherently face, which for many property owners is likely significantly higher than currently recognized. Flood insurance needs to be seen as a standard property coverage rather than a specialized addition.

4.3 Benefits of Private Sector Involvement

The NFIP currently has very little variance in the types and limits of the coverages they offer compared to what is offered by the private market for similar insurance against non-flood perils. Private companies can compete by exceeding the limits of what the NFIP will cover through offerings such as business interruption insurance, living expenses while property is repaired, basement coverage, coverage for other structures on property, and higher coverage limits. Private companies could also include flood as part of a standard homeowners' policy therefore eliminating the problem of distinguishing between wind and flood damage after intense storms. Private companies can also streamline the application process and shorten the NFIP's current 30-day waiting period before coverage goes into effect. All of these possibilities benefit consumers by giving them a wider variety of coverage options which allows them to purchase individualized coverage that better meets their needs. With greater market participation and competition, many consumers may be able to find coverage at rates lower than the cost of NFIP coverage.

5 The Future of Flood Insurance

With the May 2019 reauthorization of the NFIP still pending and the expansion of private flood coverage beginning to take hold, the future of United States flood insurance is still widely uncertain. Most experts believe that the NFIP will continue to operate in some capacity although their role may continue to evolve over time. FEMA is currently working to strengthen the NFIP's position as an insurance provider through acknowledging the financial shortcomings of the NFIP's current insurance operations and actively working to revise many of the policies that contributed to the extensive accumulation of debt. While the NFIP will likely always act as an insurer to some extent through providing coverage to high risk properties the private market is unwilling to take on, FEMA may shift their focus as private insurers continue to grow their market share.

It is imperative that FEMA continue their support of floodplain management and risk mitigation even if no longer as a part of the NFIP. As the only entity to exist with this focus as a central function, the continuation of these efforts is critical to the resiliency of the United States. Private insurance providers are still faced with extensive obstacles they have to overcome in order to increase their market share of flood coverage, but they have made it apparent they are up for the challenge. It is unknown what the interaction between the public and private sectors will be as these changes continue to shape the future of the United States' flood insurance market.

5.1 Proposed Market Structure

In the discussions around what the future of flood insurance might look like for the United States, a variety of models have been considered that outline alternative ways the private and public sectors may share flood risk exposure (Friedman, n.d.). Figure 7 outlines the estimated ease of implementation and degree of risk sharing for each model.

The Crop Insurance Model

Private carriers write a certain level of coverage and reinsure catastrophic levels with the federal government. Additionally, more protection can be added and risk spread through reinsurers offering excess-of-loss coverage to cap the government's aggregate exposure. The advantage to this is that federal funds are only required to cap the industry's maximum loss in intense catastrophe years.

The Reinsurance Model

This is similar to what currently exists. The NFIP spreads their risk by purchasing reinsurance from the private sector. This model can be structured in different ways with reinsurance taking on high-level losses, or middle-range losses (with the NFIP coming back in to cover high losses). With the Biggert-Waters Act already allowing the NFIP to secure reinsurance, the implementation of this model is relatively simple, and one of the biggest benefits is the flexibility of reinsurance program structures.

The Capital Market Model

In addition to private primary and reinsurance, capital market avenues, such as catastrophe bonds, are used to further spread risk. The use of catastrophe bonds for spreading wind and earthquake exposures is well established, so continuing to expand this practice to flood risks should be relatively straightforward.

The Pooling Model

Set up a flood insurance pool, similar to that of the California Earthquake Authority (CEA), where participating insurers can sell flood coverage bundled with standard homeowners insurance. Insurers have the advantage of pooling their resources and paying out of that pool, therefore diversifying their risks. There are many skeptics of this concept as the CEA resilience has not been tested by an actual loss event. Additionally, there is potential for a low take-up rate given the cost of coverage for high-risk properties.

The Partial Privatization Model

Private markets pick up moderate flood risks while leaving the NFIP in place for those who cannot get coverage through the private market. This model has the potential to exacerbate the adverse selection issue that already exists in the NFIP and leave the program financially unstable even if actuarially fair prices are charged.

The Bundling Model

This is based on the United Kingdom flood insurance program structure. Flood insurance is included in standard homeowner's policies and is a mandatory coverage. Additionally, the government is reducing flood exposures through infrastructure development. This would ensure everyone has coverage therefore removing the issue of adverse selection and insurers would have a large enough pool to diversify their exposure and keep premiums at an affordable rate. Homeowners who face minimal flood risk may be angry about the mandate to buy coverage they do not feel they need.

The 'Opt-Out' Model

Requiring that all property owners are offered flood insurance along with their standard homeowners policy but being allowed to opt-out of that coverage. This could boost coverage participation similar to how opt-out provisions boosted employee participation in 401(k) plans. Additionally, participation can be increased by having those who turned down coverage become ineligible for federal disaster assistance if an event occurs; there is wide skepticism if the government would be able to follow through on this pledge.

The ‘Lend a Hand’ Model

The federal government, or individual states, offer financial support to high-risk homeowners who cannot afford to pay risk-based rates for flood insurance or to help them mitigate flood exposure. Connecticut has already implemented such a policy with their Shoreline Resiliency Fund to provide low-interest rate to flood prone property owners to elevate their homes.

The ‘It Takes A Village’ Model

Flood insurance sold on a community-rated basis, similar to group health insurance, where residents can pay a lower premium than if they bought individual coverage. By improving affordability, more homeowners in flood prone areas may purchase coverage, and local governments may be more motivated to implement flood mitigation efforts. This approach could be utilized by the NFIP or private carriers. The Homeowner Flood Insurance Affordability Act of 2014 required that FEMA study the feasibility of incorporating a community-rating option into the NFIP.

These models are not mutually exclusive, and the future of flood insurance will likely be a combination of these proposed ideas. It is unlikely that the NFIP will disappear completely in the May 2019 renewal, and there is a high chance that the federal government will continue to be involved in the future of flood insurance, whatever that may be.

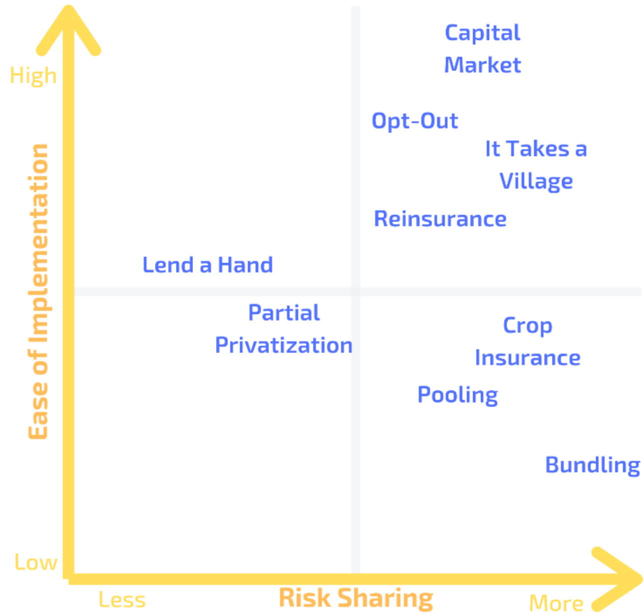

Figure 7 (Friedman, n.d.)

6 Conclusion

Flood insurance in the United States is changing. Private insurers have shown a clear intent to enter the market as alternative coverage providers. Even faced with many obstacles still to overcome, there's no question that they will continue to increase their market share. The NFIP plays too vital a role in the management and mitigation of flood risk to ever cease operations, but as a result of increased private flood offerings NFIP policies and focuses are developing as well. However, even with all these changes to the market, one thing has remained the same: the vast degree of flood underinsurance throughout the United States.

Whether offered through the NFIP or private companies, in order for flood insurance to be successful, the problem of underinsurance has to be addressed. Only an estimated 15% of homeowners in the U.S. carry flood insurance and of those many do not carry sufficient levels of coverage (Insurance Information Institute, 2018). Underinsurance directly leads to the problem of adverse selection and was a motivation behind the initial development of the NFIP.

Currently property owners see themselves as either needing flood coverage or not. This perception was exacerbated by the implementation of the mandatory purchase requirement; a property either lies within a special flood hazard area and therefore needs the mandated coverage or is outside the SFHA and therefore risk is minimal, and no coverage is needed. This has led to the extensive underinsurance that currently exists as an estimated 3 times as many properties lie within 1-in-100 year floodplains than is currently indicated by FIRM maps (Adriano, 2018). Property owners need to be made aware of the true level of risk they face; just because their property has never flooded before doesn't mean it never will, especially with flood risk exposure continually evolving.

The underinsurance of flood risk can have serious financial consequences. As the damage from storms continues to increase, proper insurance coverage is a crucial element in securing the ability of individual property owners as well as communities as a whole to rebuild. Widespread flood insurance is a necessity in order to ensure resilience as communities continue to be faced with extreme flooding events. In order for any progress to be made, the discussion around flood insurance has to change.

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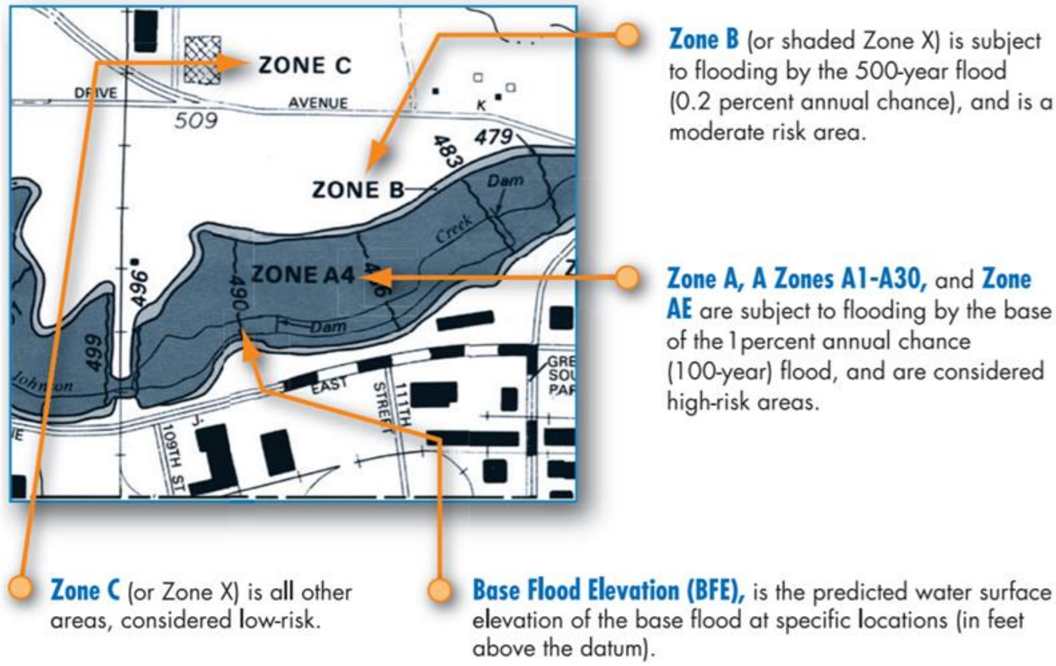
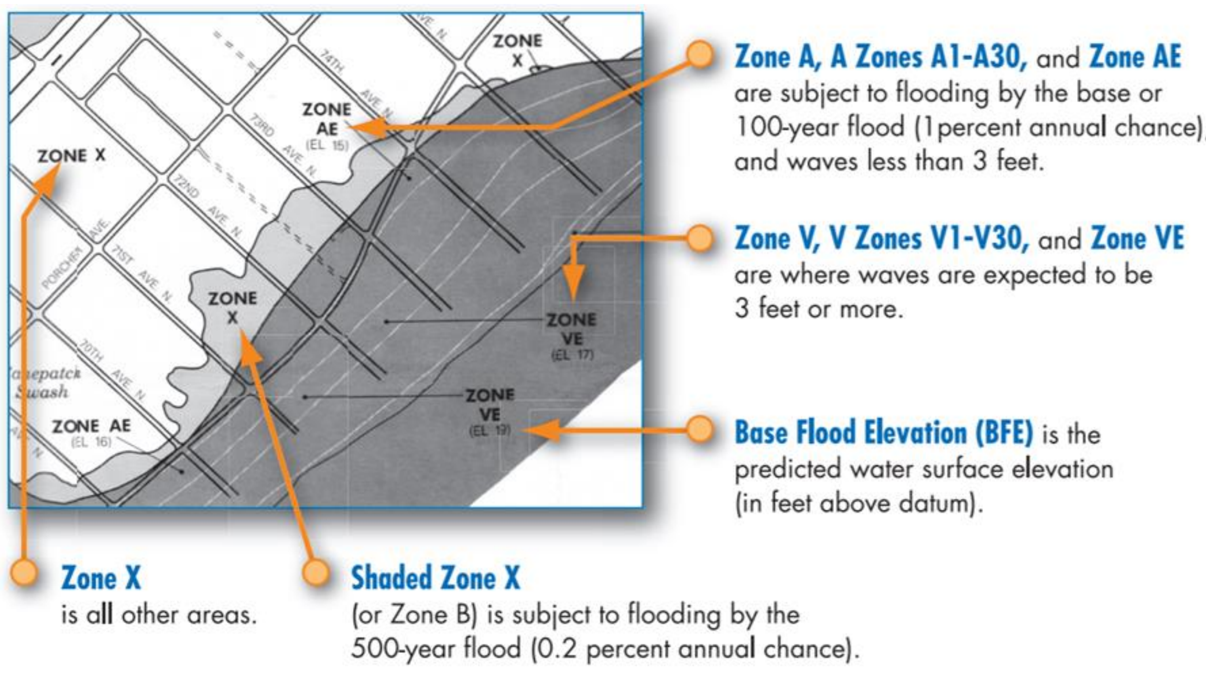
Appendix A: FIRM Maps and Flood Hazard Zones[2]

Riverine Flood Hazard Zones



Coastal Flood Hazard Zones



[2] FEMA. (n.d.). General Design Considerations. In *Making Critical Facilities Safe From Flooding*. Retrieved May 1, 2019, from https://www.fema.gov/media-library-data/20130726-1557-20490-2194/fema543_chapter2.pdf

Appendix B: Companies and Subsidiaries Participating in National Flood Insurance Program Write-Your-Own Program as of March 2019[3]

1. **Allstate Insurance Company**
    a. Allstate New jersey Insurance Company
2. **American Capital Assurance Corporation**
3. **American Commerce Insurance Company**
    a. Citation Insurance Company
    b. Commerce Insurance Company
    c. Commerce West Insurance Company
    d. Mapfre Insurance Company
    e. Mapfre Insurance Company of New York
4. **American Family Mutual Insurance Company**
    a. American Family Insurance Company
5. **American National Property and Casualty Company**
6. **American Strategic Insurance Corporation**
    a. ACA Home Insurance Corporation
    b. ASI Assurance Corporation
    c. ASI Lloyds
    d. ASI Preferred Insurance Corporation
    e. ASI Select Insurance Corporation
7. **American Traditions Insurance Company**
8. **Assurant, DBA: American Bankers Insurance Company of Florida**
9. **Auto Club South Insurance Company**
10. **Auto-Owners Insurance Company**
    a. Owners Insurance Company
11. **Baldwin Mutual Insurance Company**
12. **Bankers Insurance Group, DBA: First Community Insurance Company**
    a. Bankers Insurance Company
    b. Bankers Specialty Insurance Company
13. **Capitol Preferred Insurance Company**
14. **Centauri Specialty Insurance Company**
15. **Cooperativa de Seguros Multiples de Puerto Rico**
16. **Cornerstone National Insurance Company**
17. **CSAA Insurance Exchange**
    a. ACA Insurance Company
    b. Western United Insurance Company
18. **Everett Cash Mutual Insurance Company**
19. **Farm Family Casualty Insurance Company**
20. **Farmers Insurance Group/DBA Fire Insurance Exchange**
    a. Civic Property & Casualty Company
    b. Farmers Insurance Company
    c. Farmers Insurance Company of Arizona
    d. Farmers Insurance Company of Idaho
    e. Farmers Insurance Company of Oregon
    f. Farmers Insurance Company of Washington
    g. Farmers Insurance Exchange
    h. Farmers Insurance of Columbus
    i. Farmers New Century Insurance Company
    j. Foremost Insurance Company of Grand Rapids
    k. Michigan Illinois Farmers Insurance Company
    l. Mid-Century Insurance Company
    m. Texas Farmers Insurance Company
    n. Truck Insurance Exchange
21. **FedNat Insurance Company**
22. **First American Property & Casualty Insurance Company**
23. **First Insurance Company of Hawaii**
24. **First Protective Insurance Company**
25. **Florida Family Insurance Company**
26. **Gulfstream Property and Casualty Insurance Company**
27. **Hartford Fire Insurance Company**
    a. Hartford Fire Insurance Company of the Midwest
28. **Hartford Underwriters Insurance Company**
29. **Homesite Insurance Company**
    a. Homesite Indemnity Company
    b. Homesite Insurance Company of California
    c. Homesite Insurance Company of Florida
    d. Homesite Insurance Company of Georgia
    e. Homesite Insurance Company of Illinois
    f. Homesite Insurance Company of New York

[3] FEMA. (2019, January 30). Write Your Own Flood Insurance Company List. Retrieved May 1, 2019, from https://www.fema.gov/wyo_company

g. Homesite Insurance Company of the Midwest
h. Homesite Lloyd's of Texas

30. Integrand Assurance Company

31. Island Insurance Company

32. Liberty Mutual Fire Insurance Company

33. Mapfre PRAICO Insurance Company

34. Metropolitan Property & Casualty Insurance Company

a. Metropolitan Direct Property & Casualty Insurance Company

35. Multinational Insurance Company

36. National General Insurance Company

a. Imperial Fire & Casualty Insurance Company
b. Integon Casualty Insurance Company
c. Integon General Insurance Company
d. Integon Indemnity Corporation
e. Integon National Insurance Company
f. Integon Preferred Insurance Company
g. MIC General Insurance Corporation
h. National General Assurance Company
i. National General Insurance Company
j. National General Insurance Online, Inc.
k. New South Insurance Company

37. NGM Insurance Company

a. Main Street America Assurance Company
b. Old Dominion Insurance Company

38. Occidental Fire & Casualty Company of North Carolina

39. Pacific Indemnity Insurance Company

40. Philadelphia Contributionship Insurance Company

a. Germantown Insurance Company

41. Philadelphia Indemnity Insurance Company

42. Pilgrim Insurance Company

a. High Point Preferred Insurance Company
b. Mount Washington Assurance Corporation
c. Palisades Property & Casualty Insurance Company
d. Plymouth Rock Assurance Corporation

43. Prepared Insurance Company

44. Privilege Underwriters Reciprocal Exchange

45. QBE Insurance Corporation

46. Safepoint Insurance Company

47. Selective Insurance Company of America

a. Selective Casualty Insurance Company
b. Selective Fire & Casualty Insurance Company
c. Selective Insurance Company of New England
d. Selective Insurance Company of New York
e. Selective Insurance Company of South Carolina
f. Selective Insurance Company of the Southeast

48. Southern Farm Bureau Casualty Insurance Company

a. Florida Farm Bureau General Insurance Company
b. Georgia Farm Bureau Mutual Insurance Company
c. Kentucky Farm Bureau Mutual Insurance Company
d. Louisiana Farm Bureau Casualty Insurance Company
e. Mississippi Farm Bureau Mutual Insurance Company
f. North Carolina Farm Bureau Mutual Insurance Company
g. South Carolina Farm Bureau Mutual Insurance Company
h. Virginia Farm Bureau Mutual Insurance Company

49. Southern Fidelity Insurance Company

50. Union Mutual Fire Insurance Company

51. United Property & Casualty Insurance Company

52. United Surety & Indemnity Company

53. Universal Insurance Company (PR)

54. Universal Insurance Company of North America

55. Universal North America Insurance Company

56. USAA General Indemnity Company

57. Westfield Insurance Company

58. White Pine Insurance Company

59. Windsor-Mount Joy Mutual Insurance Company

60. Wright National Flood Insurance Company

Appendix C: Companies Participating in NFIP Reinsurance[4]

2019

Allied World Insurance Company
Antares (Lloyd's Synd. No. 1274 AUL)
Apollo (Lloyd's Synd. No. 1969 APL)
Ariel Re (Lloyd's Synd. No. 1910 ARE)
Ascot (Lloyd's Synd. No. 1414 ASC)
AXIS Reinsurance Co
Brit (Lloyd's Synd. No. 2987 BRT)
Canopius (Lloyd's Synd. No. 4444 CNP)
Chaucer (Lloyd's Synd. No. 1084 CSL)
Faraday (Lloyd's Synd. No. 0435 FDY)
Hannover Ruck SE
Hiscox (Lloyd's Synd. No. 0033 HIS)
Liberty Mutual Insurance Company
Liberty Specialty Services Ltd. Paris o/b/o (Lloyd's Synd. No. 4472 LIB)
Markel Global Reinsurance Co
MS Amlin (Lloyd's Synd. No. 2001 AML)
Munich Reinsurance America, Inc.
Navigators US
Renaissance (Lloyd's Synd. No. 1458 RNR)
Renaissance Reinsurance U.S. Inc.
SCOR Reinsurance Company
Swiss Reinsurance America Corporation
The Cincinnati Insurance Co
Transatlantic Re o/b/o General Reinsurance Corporation
Transatlantic Reinsurance Company
Validus Americas o/b/o Validus Reinsurance (Switzerland) Ltd.
XL Catlin (Lloyd's Synd. No. 2003 XLC)
XL Reinsurance America, Inc.

2018

Allied World Insurance Company
Amlin (Lloyd's Synd. No. 2001 AML)
Apollo (Lloyd's Synd. No. 1969 APL)
Ariel (Lloyd's Synd. No. 1910 ARE)
Ascot (Lloyd's Synd. No. 1414 ASC)
AXIS Reinsurance Co US
Brit (Lloyd's Synd. No. 2987 BRT)
Canopius (Lloyd's Synd. No. 4444 CNP)
Chaucer (Lloyd's Synd. No. 1084 CSL)
Faraday (Lloyd's Synd. No. 0435 FDY)
General Reinsurance Corporation
Hannover Ruck SE
Hiscox (Lloyd's Synd. No. 0033 HIS)
Liberty Mutual Insurance Company
Liberty Specialty Services Ltd. Paris o/b/o (Lloyd's Synd. No. 4472 LIB)
Managing Agency Partners (Lloyd's Synd. No. 2791 MAP)
Markel Global Reins Co
Munich Reinsurance America, Inc.
QBE Reinsurance Corporation
Renaissance (Lloyd's Synd. No. 1458 RNR)
Renaissance Reinsurance U.S. Inc.
SCOR Reinsurance Company
Swiss Re Underwriters Agency, Inc. o/b/o Swiss Reinsurance America Corporation
The Cincinnati Insurance Co

[4] FEMA. (2019, April 24). National Flood Insurance Program's (NFIP) Reinsurance Program. Retrieved May 1, 2019, from https://www.fema.gov/nfip-reinsurance-program

Transatlantic Reinsurance Company
Validus Reinsurance (Switzerland) Ltd.
XL Catlin (Lloyd's Synd. No. 2003 XLC)
XL Reinsurance America, Inc.

2017

Amlin (Lloyd's Synd. No. 2001)
Ascot (Lloyd's Synd. No. 1414)
Axis Reinsurance Company U.S.
Brit (Lloyd's Synd. No. 2987)
Everest Reinsurance Company
Faraday (Lloyd's Synd. No. 0435)
General Reinsurance Company
Hannover Ruck SE
Hiscox (Lloyd's Synd. No. 0033)
Liberty Mutual Insurance Company
Liberty Specialty Markets (Lloyd's Synd. No. 4472)
Market Global Reinsurance Company
Munich Reinsurance America Inc.
National Indemnity (U.S.)
Partner Reinsurance Company of the U.S.
QBE Reinsurance Corporation
Renaissance Re (Lloyd's Synd. No. 1458)
Renaissance Reinsurance U.S. Inc.
SCOR Reinsurance Company
Sompo Canopius (Lloyd's Synd. No. 4444)
Swiss Reinsurance America Corporation
Transatlantic Reinsurance Company
Validus Reinsurance (Switzerland) Ltd.
XL Catlin (Lloyd's Synd. No. 2003)
XL Reinsurance America Inc.

Appendix D: A Simple Excel Based Catastrophe Model and its Applications

When broken down to the most basic level, catastrophe models contain four main components: the probability of an event, intensity/effect of an event, property values, and insured losses. I was able to utilize VBA code and the macro function in Excel to create a simplified catastrophe model. In order to illustrate how an insurer may utilize the results from a catastrophe model, I then took my simulated results and applied them to the calculation of premiums under a community rating as well as a risk-based rating system. This appendix details the development of the sample catastrophe model, including how basic assumptions were developed, as well as the application of results to the aforementioned rating systems.

It is important to note that although flooding events are spread out over many years and the actual cost of them to insurers would therefore be impacted by the time value of money, this factor was left out of the model. This was intentional due to the high variation in interest rates and home values over time as well as for simplicity's sake.

Set-Up

The first step of model development was to set up the excel sheet that will be populated with input assumptions and simulated results. The image below shows the section of the worksheet where the modeler's assumptions are input; all cells highlighted in blue can be changed and are used for calculations within the simulation. The user assumptions for all of these inputs should be entered before running the simulation. The first four inputs that the simulation user should consider are:

Coverage Limit, the amount of coverage available for purchase;

Cost per Inch, the average damage to a home caused by one inch of floodwater;

Homes, the number of homes theoretically in the insurers portfolio in this area or the number of homes to be simulated for each flooding event; and

Years, the number of years for which potential events will be simulated.

Here, coverage limit is set to reflect the NFIP maximum coverage for a single-family home, and cost per inch is set to the average found during research, while homes and years are up to the discretion of the user and may vary based upon why they are employing the simulation. The motivation for all other assumption inputs selected below will be explained as they are referenced throughout the simulation.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Poisson Mean**	0.02	**Distance**		**Value**	Mean	SD	**Elevated**	15%	**Flood**		**Multiplier**	1
2			Mean	750	Dis <750	$ 400,000.00	$ 45,000.00			<=100	14.56		
3	**Coverage Limit**	$ 250,000.00	SD	150	Dis >= 750	$ 200,000.00	$ 40,000.00			<=500	8.83		
4	**Cost per Inch**	$ 20,000.00								<=1000	4.12		
5	**Homes**	10	Simulate!							>1000	1.96		
6	**Years**	500											
7	**Events**	12											

	A	B
9		
10	**Year**	**# of Events**
11	1	0
12	2	0

The fields illustrated to the left create the space for the simulation to input the number of flooding events that happen each year. The year column is populated to reflect the number of years chosen as an input above starting with 1 input into cell A11 and using the formula "=IF(A11<B6,A11+1,"")" to populate the remainder of the column.

The other two fields illustrated here create the space for the simulation to input the modeled results for each home in each flooding event as well as calculated totals and averages for each event.

	D	E	F	G	H	I	J	K
9								
10	Event	Home	Distance (ft)	Value	Elevated?	Flood Depth (in)	Damage	Claim

	M	N	O	P	Q	R	S	T
9								
10	Event	Avg Distance	Avg Value	Avg Depth	Total Damage	Avg Damage	Total Claim	Avg Claim
11								

Simulation

```
Sub Simulation()

Range("B11:B1050").ClearContents
Range("D11:K1048567").ClearContents
Range("M11:T1048567").ClearContents
```

The first line of VBA code that begins the simulation names it appropriately "Simulation." The following 3 lines clear the cells where results will be input so that any results from previous simulation runs are removed.

The first thing that the simulation calculates is the number of flooding events that occur each year. This is done using a Poisson distribution; this distribution works well as it expresses the probability of a given number of events occurring within a specified timeframe given that events are independent of one another when the approximate rate of occurrence is known. The simulation user inputs their assumption of the frequency of flooding events into the Poisson Mean input cell. In this example, we are assuming a 1-in-50 year floodplain; therefore, our input for Poisson mean is the number of flooding events we expect to have each year, which in this case is 1/50, or 0.02. When the user inputs this assumption it automatically updates the "Poisson" worksheet (illustrated to the left) to reflect this mean. The table in this worksheet calculates the probability distribution function (PDF) as well as cumulative distribution function (CDF) for values reflecting the number of flooding events that occur each year.

	A	B	C	D	E	F	G
1	Lambda	0.02					
2							
3		x	P(X=x)	P(X<=x)	Low	High	Value
4		0	0.980199	0.980199	0	0.980199	0
5		1	0.019604	0.999803	0.980199	0.999803	1
6		2	0.000196	0.999999	0.999803	0.999999	2
7		3	1.31E-06	1	0.999999	1	3
8		4	6.53E-09	1	1	1	4
9		5	2.61E-11	1	1	1	5
10		6	8.71E-14	1	1	1	6
11		7	2.49E-16	1	1	1	7
12		8	6.22E-19	1	1	1	8
13		9	1.38E-21	1	1	1	9
14		10	2.77E-24	1	1	1	10

When the simulation is run, it first determines the number of years to simulate based on the user input for Years. Then for each of these years it simulates a random value between 0 and 1 reflecting the CDF of the number of flooding events that occur within that year. The corresponding number of events is then read from the "Poisson" worksheet and input into the corresponding cell within column B of the worksheet. The VBA code that executes is provided below.

```
Sub Stochast()

Simulate = Excel.Cells(6, 2)

For y = 1 To Simulate
    Randomize Timer
    s = Rnd
    Events = Application.WorksheetFunction.VLookup(s, Sheets("Poisson").Range("E4:G14"), 3, True)
    Excel.Cells(10 + y, 2) = Events
Next y
```

After the number of flooding events for each year is simulated, the total number of events that occurred over all years is calculated in cell B7 with the formula "=SUM(B11:B1048576)". This total number of events along with the number of homes per event that the user wishes to simulate and input into the Homes input cell are then read into the simulation.

```
Events = Excel.Cells(7, 2) 'Define # of flood events
Homes = Excel.Cells(5, 2) 'Define # of homes per event
```

```
For e = 1 To Events

For h = 1 To Homes

    'Label event #
    Excel.Cells(h + 10 + (e - 1) * Homes, 4) = e

    'Label house #
    Excel.Cells(h + 10 + (e - 1) * Homes, 5) = h
```

The simulation then begins to calculate values for the first home in the first flooding event and starts by labeling the row with the appropriate event and home number within the section of the worksheet designated for displaying the simulation results.

```
'simulate distance from water
dmean = Excel.Cells(2, 4)
dsd = Excel.Cells(3, 4)

Randomize Timer
d = Rnd
Distance = WorksheetFunction.Norm_Inv(d, dmean, dsd)
Excel.Cells(h + 10 + (e - 1) * Homes, 6) = Distance
```

The first value that the simulation calculates for each home is its distance from the water source that is serving as the source of flooding. These distances are modeled as following a normal distribution with a mean and standard deviation that are defined by the user in the inputs. For this example, I examined these values for a beach in North Carolina and chose to use an average distance of 750 ft from the coast, with a standard deviation of 150 ft. The simulation produces a random value between 0 and 1 to serve as the CDF of the distribution. The distance from the coast is then calculated using this CDF value and the inputs for distribution mean and standard deviation.

```
'simulate home value based on distance
cmean = Excel.Cells(2, 6)
csd = Excel.Cells(2, 7)
fmean = Excel.Cells(3, 6)
fsd = Excel.Cells(3, 7)

Randomize Timer
v = Rnd
    If Distance < 750 Then
        Value = WorksheetFunction.Norm_Inv(v, cmean, csd)
    ElseIf Distance > 750 Then
        Value = WorksheetFunction.Norm_Inv(v, fmean, fsd)
    End If
Excel.Cells(h + 10 + (e - 1) * Homes, 7) = Value
```

The next attribute that is calculated for each home is the home value, which is based on the previously calculated distance. The reasoning behind basing value on distance is that the value of homes on the coast is typically higher than for those near the coast. In the development of this section I used Zillow to look at the values of homes in Topsail Beach, North Carolina. It was found that 750 ft from the coast served as a good cutoff for where the average home value began to change. Zillow was also used to find the average and standard deviation of home values for both homes that were less than 750 feet from the coast as well as those that were further than 750 feet. It was found that homes within 750 ft of the coast had an average value of $400,000 and a standard deviation of $45,000 while those further out had a mean of $200,000 and standard deviation of $40,000.

The simulation first simulates a random value between 0 to 1 to represent the CDF of the distribution and then employs the use of 'If Then' functions to calculate the home value using the appropriate mean and standard deviation determined by the home's distance.

```
'simulate if home is elevated
binom = Excel.Cells(1, 9)

Randomize Timer
b = Rnd
    If b < binom Then
        Elev = "yes"
    ElseIf b > binom Then
        Elev = "no"
    End If
Excel.Cells(h + 10 + (e - 1) * Homes, 8) = Elev
```

The model also includes the consideration that some homes along the coast have been elevated to decrease their chance of flooding. The simulation of this is based on a binomial distribution (as a home is either elevated or not), and the simulation user inputs what they believe to be the mean percentage of homes elevated in the area they are analyzing. Through looking at photographs of the North Carolina coast it was determined that around 15% of homes are elevated, so that was the assumption used in this example. The simulation produces a random number between 0 and 1, and if the value is below the average it is labeled as elevated (and if above the average labeled as not elevated).

```
'simulate flood height based on if elevated and on distance
multiplier = Excel.Cells(1, 13)
high = Excel.Cells(2, 11) * multiplier
med = Excel.Cells(3, 11) * multiplier
low = Excel.Cells(4, 11) * multiplier
xlow = Excel.Cells(5, 11) * multiplier

Randomize Timer
f = Rnd
    If Elev = "yes" Then
        Flood = 0
    ElseIf Distance <= 100 Then
        Flood = -high * Log(1 - f)
    ElseIf Distance <= 500 Then
        Flood = -med * Log(1 - f)
    ElseIf Distance <= 1000 Then
        Flood = -low * Log(1 - f)
    ElseIf Distance > 1000 Then
        Flood = -xlow * Log(1 - f)
    End If
Excel.Cells(h + 10 + (e - 1) * Homes, 9) = Flood
```

The simulation then calculates the height of flood water within the home based on whether or not the home is elevated as well as the distance of the home from the coast. It is assumed that if the home is elevated it is high enough that it does not flood. For homes that are not elevated, the depth of flood water is modeled as an exponential distribution with a mean based upon the homes distance from the coast. Varying mean by distance accounts for higher flood waters in homes closer to the coast while the use of an exponential distribution accounts for variations in land elevation and home foundation characteristics. Research found that for homes 100 ft or less from the coast, flood heights averaged 14.56 inches, for those greater than 100 ft but less than or equal to 500 ft heights averaged 8.83 ft, for those greater than 500 ft but less than or equal to 1000 ft heights averages 4.12 inches, and for those greater than 1000 ft flood height averaged 1.96 in. Additionally, a multiplier is added to these inputs which could be used to simulate the effect of variations in storm impact due to climate change, or land development changes. This is not something that this example will be exploring so the multiplier was set to 1. The model simulates a random number from 0 to 1, which again is used as the CDF in calculating the flood depth within the home from an exponential distribution with the correct mean corresponding to the home's distance from the coast.

The model then calculates the damage to the home and resulting claim amount based on the depth of flood water as well as the home value. The cost of damage is found by taking the flood depth and multiplying by the input for cost per inch. However, as damage to a home cannot be more than the home's value, the home value was set as a maximum for the damage calculation. The claim amount is then found by determining if the damage to the home is above or below policy limit; if damage is below the limit then the claim amount is equal to damage, but if it is above, then the claim amount is equal to the policy limit.

```
'Caluculate Damage
Cost = Excel.Cells(4, 2) * Flood
    If Cost < Value Then
        Damage = Cost
    ElseIf Cost > Value Then
        Damage = Value
    End If
Excel.Cells(h + 10 + (e - 1) * Homes, 10) = Damage

'Calculate Claim
Limit = Excel.Cells(3, 2)
    If Damage < Limit Then
        Claim = Damage
    ElseIf Damage > Limit Then
        Claim = Limit
    End If
Excel.Cells(h + 10 + (e - 1) * Homes, 11) = Claim
```

The simulation then repeats calculations for distance, value, if elevated, flood depth, damage, and claim for the number of specified homes. After the values for each home have been calculated, the model calculates the average distance, average value, average depth, total damage, average damage, total claim, and average claim for the event by using all the homes for that event. The model then moves on to the next event and again simulates all the data for the number of homes specified and produces the summary data at the end. After all the homes for all of the events have been simulated, the model produces the same summary statistics for all homes across all events.

```
Next h

Excel.Cells(10 + e, 13) = e
'Caclculate average distance
EventDistance = WorksheetFunction.AverageIf(Range("D11:D1048576"), e, Range("F11:F1048576"))
Excel.Cells(10 + e, 14) = EventDistance
'Calculate average home value
EventValue = WorksheetFunction.AverageIf(Range("D11:D1048576"), e, Range("G11:G1048576"))
Excel.Cells(10 + e, 15) = EventValue
'Calculate average depth
EventDepth = WorksheetFunction.AverageIf(Range("D11:D1048576"), e, Range("I11:I1048576"))
Excel.Cells(10 + e, 16) = EventDepth
'Calculate total and average damage
EventDamage = WorksheetFunction.SumIf(Range("D11:D1048576"), e, Range("J11:J1048576"))
Excel.Cells(10 + e, 17) = EventDamage
Excel.Cells(10 + e, 18) = EventDamage / Homes
'Calculate total and average claim
EventClaim = WorksheetFunction.SumIf(Range("D11:D1048576"), e, Range("K11:K1048576"))
Excel.Cells(10 + e, 19) = EventClaim
Excel.Cells(10 + e, 20) = EventClaim / Homes
Next e

Excel.Cells(11 + Events, 13) = "Total"
TotalDistance = WorksheetFunction.Average(Range("F11:F1048576"))
Excel.Cells(11 + Events, 14) = TotalDistance
TotalValue = WorksheetFunction.Average(Range("G11:G1048576"))
Excel.Cells(11 + Events, 15) = TotalValue
TotalDepth = WorksheetFunction.Average(Range("I11:I1048576"))
Excel.Cells(11 + Events, 16) = TotalDepth
TotalDamage = WorksheetFunction.Sum(Range("J11:J1048576"))
Excel.Cells(11 + Events, 17) = TotalDamage
Excel.Cells(11 + Events, 18) = TotalDamage / (Homes * Events)
TotalClaim = WorksheetFunction.Sum(Range("K11:K1048576"))
Excel.Cells(11 + Events, 19) = TotalClaim
Excel.Cells(11 + Events, 20) = TotalClaim / (Homes * Events)

End Sub
```

The resulting data can then be used by insurers in various ways. They could run multiple simulations while varying one of the inputs to examine the sensitivity of the model to different inputs. They could compare the results of insuring homes in one geographic location to another by changing multiple inputs to reflect the differences between locations. They could also use the modeled results to aid them in determining appropriate rates to charge customers, which is an idea that we will explore further here.

Application to Rating

The results of this example simulation can be used to develop rates that an insurer may charge a customer. Specifically, I looked at a simplified example of a community rating system compared to a risk based premium rating system.

In this simplified community rating system, it is assumed that all homes will be charged the same premium regardless of their risk exposure which results in low-risk homes subsidizing a portion of the premium for higher risk homes. (This is more simplified than a standard community rating model where risk exposure is considered to some extent.) The amount that would be charged to each homeowner in our simplified system would be the average claim amount * the probability of incurring a claim (number of events/500 years). For example, if the simulation is run and over the 500 years 5 flood events occur that result in an average claim amount of $55,077.35, the insurer may charge all 10 homeowners an annual premium of (5/500)*$55,077.35 = $550.77

However, the insurer would likely run the simulation multiple times to improve the accuracy of expected losses and compare multiple 500-year scenarios and the resulting premiums. The simulation was set at the baseline assumptions previously discussed in the appendix, run 8 times, and the results from each run were tracked in the following table:

Simulation	# of Events	Average Claim	Annual Premium	Monthly Premium
1	14	$61,308.26	$1,716.63	$143.05
2	16	$68,755.67	$2,200.18	$183.35
3	13	$71,120.73	$1,849.14	$154.09
4	8	$69,736.69	$1,115.79	$92.98
5	20	$57,960.06	$2,318.40	$193.20
6	11	$78,606.90	$1,729.35	$144.11
7	8	$74,472.06	$1,191.55	$99.30
8	10	$66,045.44	$1,320.91	$110.08
Average	12.5	$68,500.73	$1,680.24	$140.02

Based on these results, the insurer may choose to charge each of the 10 homeowners in this area an annual premium of $1680.24 (monthly premium of $140.02).

The simulation could also be used to develop risk-based premiums for homes in this area. Rating in this way would first require the development of loss relativities. The first step is creating categories that each of the simulated homes would fit. I chose to divide the homes based on 1) whether they are elevated and 2) their distance from the coast divided into the same categories that created the divisions for the changing flood depth mean: less than 100, between 100 and 500, between 500 and 1000, and greater than 1000. One of these categories must be chosen as the baseline, I chose a distance of 500<x<=1000 feet and not elevated as the baseline for this example as that is a common category in reality for coastal homes. Then the average claim for each of these categories was calculated, followed by the loss relativity, which is the average claim for each category divided by the average claim for the baseline category. These results for an example simulation can be seen below.

Average Claim	**Elevated**	
Distance	**No**	**Yes**
<=100	$ -	$ -
100<x<=500	$ 164,574.07	$ -
500<x<=1000	**$ 66,470.11**	$ -
x>1000	$ 41,812.76	$ -

Loss Relatives	**Elevated**	
Distance	**No**	**Yes**
<=100	0	0
100<x<=500	2.47591	0
500<x<=1000	**1**	0
x>1000	0.62905	0

The baseline premium is then calculated by taking the average claim for our baseline category and multiplying by the probability of a loss occurrence (simulated # of events/500 years). In this example our baseline premium is $1,595.28. To determine the annual premiums for the other categories, their loss representatives are multiplied by the baseline premium resulting in the following rates:

Premium	**Elevated**	
Distance	**No**	**Yes**
<=100	$ -	$ -
100<x<=500	$ 3,949.78	$ -
500<x<=1000	**$ 1,595.28**	$ -
x>1000	$ 1,003.51	$ -

In order to determine the premium actually charged, a modeler would likely repeat this process multiple times and use an average of the rates to determine what will be charged.

We see that the premium charged to the baseline group in the risk-based pricing is similar to the premium charged to everyone in community-based rating system. The difference is that in the risk-based system, homes that are further from the coast are charged a slightly lower premium while those that are closer to the coast are charged significantly more. The community rating system makes premiums significantly more affordable for high risk properties; however, lower risk homeowners may be unwilling to pay the higher price needed to subsidize the premiums of these high-risk properties. Alternatively, under the risk-based rating system, high-risk property owners may be unable to afford coverage at all.

It is important also to note the premiums calculated in both the community rating and risk-based rating examples are gross premiums that do not represent the inclusion of insurer expenses and profits; thus, the actual rate that insurers would charge would be higher than this.